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Rebuilding fish stocks no later than 2015: will Europe meet the deadline?

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Abstract

Maintaining or restoring fish stocks at levels that are capable of producing maximum sustainable yield is a legal obligation under the United Nations Convention on the *Law of the Sea* (UNCLOS) and has been given the deadline of no later than 2015 in the *Johannesburg Plan of Implementation* of 2002. Here, we analyse stock assessment data of all major fish stocks of the Northeast Atlantic to determine whether Europe will be able to deliver on this commitment, which it has helped to bring about. The analysis shows that, if current fishing pressure continues, 91% of the European stocks will remain below target. If European ministers in charge of fisheries were serious about meeting their obligations, they would have to reduce drastically fishing pressure and halt fishing completely on some stocks. But even if fishing were halted in 2010, 22% of the stocks are so depleted that they cannot be rebuilt by 2015. If current trends continue, Europe will miss the 2015 deadline by more than 30 years. We argue that, from a legal perspective, such repeated enactment of fisheries management measures, which are incapable of maintaining or restoring B_{msy}, does not comply with the requirements contained in UNCLOS and may constitute a breach of the precautionary principle of European Community law.

Keywords *Code* of Conduct, *Law of the Sea*, maximum sustainable yield, overfishing, precautionary principle

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Introduction

The poor compliance of European nations with the UN *Code of Conduct for Responsible Fisheries* (FAO 1995) has been highlighted recently and has been associated with the low priority given to improving fisheries management and with the dysfunctional Common Fisheries Policy (Pitcher *et al.* 2009). While implementation of the *Code of Conduct* is voluntary, there are also legal obligations for responsible fisheries. According to Article 61 (3) of the 1982 United Nations Convention on the *Law of the Sea* (UNCLOS 1982), coastal State fisheries management measures must be designed to restore and maintain fish stock sizes that can produce maximum sustainable yields. This obligation has been given the deadline of 2015 by the *World Summit on Sustainable Development* in Johannesburg in 2002. While the latter does not contain a legal obligation, the political weight of the rules contained therein is substantial. The European Community (EC) as well as Iceland, Norway and Russia are parties to UNCLOS, which has entered into force in 1994 (formal confirmation by the EC in 1998), and have signed the *Code of Conduct* and the *Johannesburg Plan of Implementation* (2002). Thus, halfway to the deadline, it is of interest to see how effective European fisheries management is fulfilling these legal requirements and political goals. Here, we analysed all European stocks with suitable data. In particular, we explored whether current exploitation levels will allow stocks to rebuild towards biomasses associated with maximum sustainable yield and whether this can be achieved before the deadline of 2015.

Discussion of methods

Data sets and general approach

We used data on 54 fish stocks of the Northeast Atlantic, as made available by the International Council for the Exploration of the Seas (ICES) at its web site http://www.ices.dk in December 2008, see Supporting Information for details. ICES did not directly state the key parameters needed for this study, namely intrinsic rate of population increase r_{max}, the biomass B_{msy} and fishing mortality F_{msy} associated with maximum sustainable yield, and MSY itself. A variety of methods can be used to estimate these parameters, and every method has its pros, cons and champions. Here, we applied and compared different methods for parameter estimation to demonstrate explicitly that the application of alternative methods would not have changed the overall outcome of our analysis. We used the means of the various estimates for our final analysis. The respective equations and a summary table (Table S6) of the symbols used in this study are presented in the Supporting Information.

How to represent uncertainty

Estimates of uncertainty were available for the geometric mean of recruitment, the slope of the stock–recruitment relationship, the intrinsic rate of population increase and the unexploited total biomass, from descriptive statistics and the curve fitting algorithm in NCSS (Hintze 2001), respectively. We chose 95% confidence limits as measure of uncertainty, because these can be interpreted directly, e.g. for detection of significant differences. Estimates of uncertainty were not available for several input parameters that we derived from stock assessment reports, such as natural mortality, fishing mortality, proportion mature individuals at age and mean body weight at age. We assumed that the main sources of uncertainty were the variability in recruitment, population growth rate and unexploited biomass. We therefore carried these confidence limits forward by insertion in the respective equations to derive approximate confidence limits for MSY, B_{msy} and recovery time Δt, see Supporting Information for details. The approximate confidence limits seemed realistic because they did not exceed biological limits such as predicting infinite biomasses or negative slopes of increase. Note that in the case of scientific uncertainty, the precautionary approach requires targeting of the 'safer' confidence limit, i.e. the upper confidence limit of B_{msy} and the lower confidence limits of MSY and F_{msy}.

Three methods for MSY

Maximum sustainable yield was estimated from yield-per-recruit and mean recruitment, from mean expected biomass-per-recruit and mean recruitment, and from surplus production analysis (Table S3). Of the 49 cases with available estimates from expected biomass and surplus production, 44 (90%) had overlapping confidence limits. Of the 30 available MSY estimates from yield-per-recruit analysis, all overlapped with the confidence limits of at least one of the two other estimates, and 23 (77%) overlapped with both.

Three methods for F_{msy}

Three different approaches were used for estimating fishing mortality F_{msy}, namely (i) our interpretation of ICES Advice for long-term sustainable F with high yields; (ii) half of r_{max} estimated from the surplus yield analysis; and (iii) half of r_{max} estimated from the slope of the stock–recruitment relationship (Tables S1 and S4). Of the 54 estimates of r_{max}, 40 (74%) had overlapping confidence limits. Of the 54 estimates of F_{msy} extracted from ICES documents, 51 (94%) fell within at least one of the r_{max} confidence limits (assuming $2F_{msy} = r_{max}$).

Two methods for B_{msy}

Two different approaches were used to estimate spawning biomass associated with maximum sustainable yield (B_{msy}, Tables S2 and S5). In the first approach, the number of spawners in the unfished stock N_O was estimated from the number of recruits surviving to maturity and the mean adult mortality rate. Multiplying half of N_O with the corresponding mean weight of individuals gave B_{msy}. In the second approach, expected spawning biomass-per-recruit at fish mortality F_{msy} was multiplied with the mean number of recruits. Of the estimates obtained with these two methods, 48 (89%) had overlapping confidence limits.

Consensus values

In summary, most of the estimates provided by the different methods were not significantly different and we therefore used their means for the final analysis. We believe that the selection of 'consensus values' for MSY, B_{msy} and F_{msy} and their respective confidence limits provided a sound basis for the purpose of this study.

Results and discussion

B_{msy} and F_{msy}

Biomasses and fishing mortalities associated with maximum sustainable yield are shown in Tables S4 and S5. Of the 54 stocks with suitable data in the year 2007, nine stocks (17%) had biomasses that were at or above B_{msy}. Of these stocks, four had fishing mortalities that were significantly larger than F_{msy} and thus they were likely to shrink below B_{msy}. Nine (23%) of the stocks for which ICES advised lower biomasses limits (B_{pa}) were far below that limit ($B < 2/3\ B_{pa}$) and thus in acute danger of reduced reproductive capacity and collapse. These stocks are marked bold in Table S1. The median ratio B_{pa}/B_{msy} was 0.34 (95% CL 0.28–0.44, $n = 39$).

The B/B_{msy} ratio

We used the ratio of actual stock biomass B to the biomass that can produce the maximum sustainable yield (B_{msy}) as an indicator of the status of the stocks. A scatterplot of B/B_{msy} ratios from 1950 to 2007 is shown in Fig. 1, with indication of exploitation levels. Stocks are considered precautionary exploited if their biomass is larger than the one that can produce maximum sustainable yields ($B/B_{msy} > 1$). Stocks are considered overfished if their biomass is too small to produce maximum sustainable yields ($B/B_{msy} < 1$). Stocks are considered unsafe or outside of safe biological limits if their biomass is so small that their reproductive capacity is reduced ($B/B_{msy} < 0.34$). Note that our definition of precautionary exploitation differs from the one currently used in European fisheries management, where the term is used for to stocks outside the unsafe zone with $B > B_{pa}$. Clearly, the internationally agreed

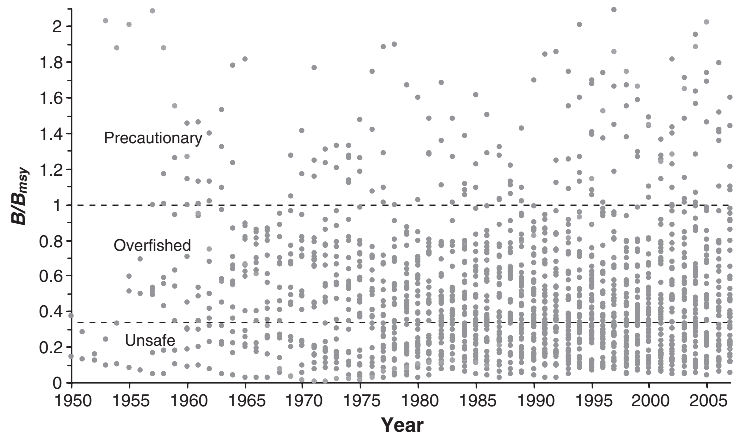

Figure 1 Scatterplot of stock biomass B relative to biomass associated with maximum sustainable yield B_{msy}, from 1950 to 2007, for 50 European stocks with available time-series data. Levels of exploitation are indicated. Stocks with biomass ratios around 1.0 would be fully exploited, delivering the maximum sustainable yield.

lower biomass limit for stocks is the one that can produce maximum sustainable yields, i.e. B_{msy} and not B_{pa}. Consequently, a precautionary level of exploitation is one that avoids crossing that limit by maintaining stocks at slightly larger levels than B_{msy}.

Figure 1 presents a visualization of the assessment of the EC Green Paper (EC 2009) that 88% of European stocks are overfished and 30% are outside of safe biological limits. Figure 2 presents an analysis of these data, with median and percentiles and indication of relevant international agreements. Throughout the time series, most stocks are far below the biomass that can produce maximum sustainable yield. From the late 1970s to the year 2000, median biomass fluctuated slightly above the lower biomass limit (B_{pa}) below which persistence of stocks is endangered. After 2000 there was a slight increase in median biomass, caused by increased biomasses of the less-overfished stocks near the 75th percentile line. However, throughout the time series there is no visible recovery of the most depleted stocks near the 25th percentile line. Extrapolating a linear regression of the 25th percentile from 1994 to 2007 results in a slightly negative slope, suggesting that international agreements did not benefit depleted stocks.

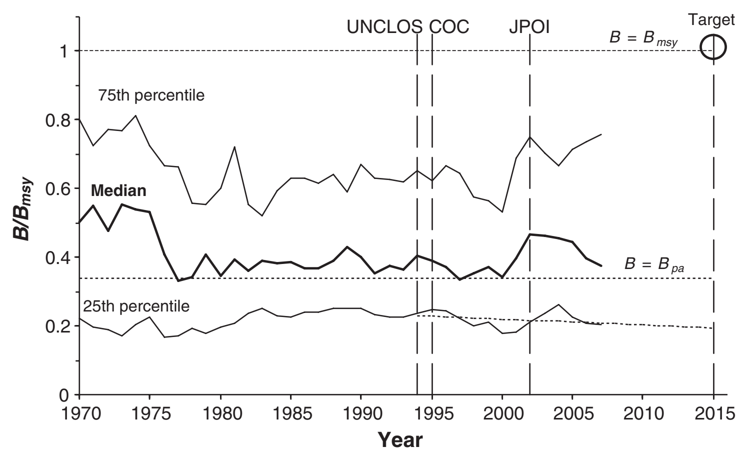

Figure 2 Time series of stock biomass B relative to biomass associated with maximum sustainable yield B_{msy}. The target biomass ratio $B = B_{msy}$ which is to be reached not later than 2015 and the biomass limit $B = B_{pa}$ are indicated by horizontal lines. The vertical broken lines indicate the dates of relevant international agreements, such as the *Law of the Sea* (UNCLOS), the *Code of Conduct for Responsible Fisheries* (COC) and the *Johannesburg Plan of Implementation* (JPOI). A dotted line extends the trend in the 25th percentile from 1994 to 2007; this line would have to meet the Target circle for compliance with JPOI.

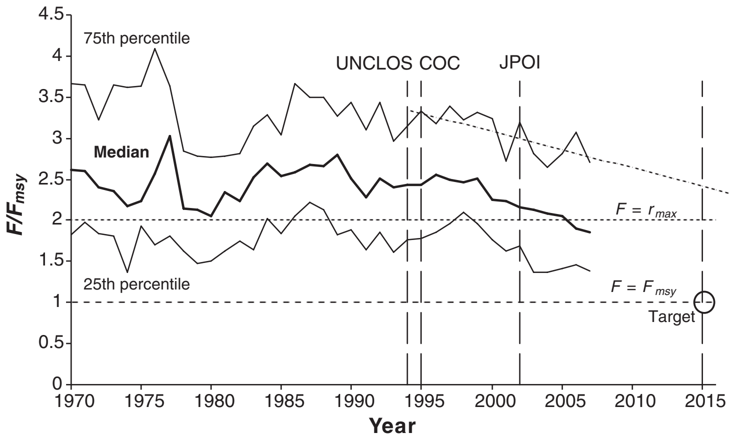

Figure 3 Time series of fishing mortality F relative to fishing mortality associated with maximum sustainable yield (F_{msy}). Dotted horizontal lines indicate the intrinsic rate of population increase r_{max} and the target F_{msy}. The vertical broken lines indicate the dates of relevant international agreements, such as the *Law of the Sea* (UNCLOS), the *Code of Conduct of Responsible Fisheries* (COC), and the *Johannesburg Plan of Implementation* (JPOI). A dotted line extends the trend in the 75th percentile from 1994 to 2007; this line would have to meet the Target circle for compliance with JPOI.

The F/F_{msy} ratio

Only six stocks (11%) had fishing mortalities that were at or below F_{msy} and 38 stocks (70%) had fishing mortalities that were significantly higher than F_{msy}. In 21 stocks (39%), including all cod stocks, fishing mortality was higher than $r_{max} = 2\ F_{msy}$, suggesting that current management will shrink these stocks towards biomasses outside of safe biological limits.

F_{msy} is the fishing mortality that would allow the stock to stabilize around a biomass level that can produce the maximum sustainable yield. We used the ratio of the actual fishing mortality F to F_{msy} as an indicator of management efforts towards meeting the legal requirements and political goals of sustainable fisheries. A time series of the median F/F_{msy} ratio is shown in Fig. 3. Restoring depleted stocks to B_{msy} requires that F is at least temporarily smaller than F_{msy}. However, throughout most of the time

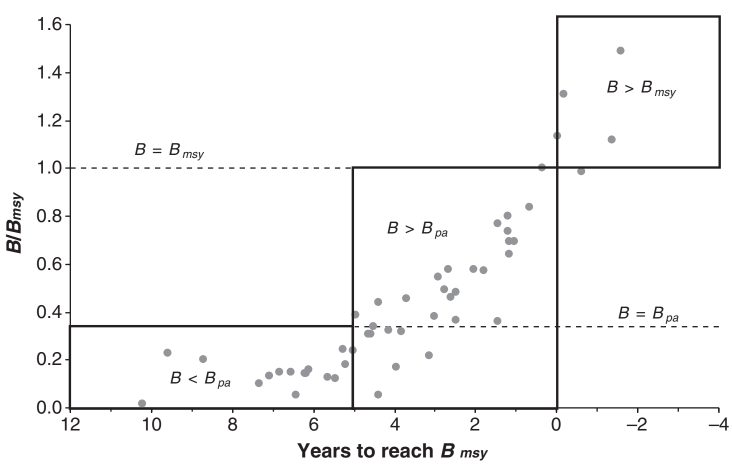

Figure 4 Time needed to reach the biomass associated with maximum sustainable yield (B_{msy}) if fishing is halted, with indication of the biomass limit B_{pa}. The lower-left box contains stocks with biomasses below median B_{pa}, which will be unable to rebuild by 2015. The middle box contains stocks that will be able to meet the deadline without or with very modest fishing. The upper-right box contains stocks that have already reached the target stock size. The time needed for increasing to B_{msy} is shown for each stock in Table S5.

series median fishing mortality is even larger than the intrinsic rate of population increase r_{max}, i.e. larger than the maximum growth potential of the stocks. The *Law of the Sea* (UNCLOS) and the *Code of Conduct* had apparently no immediate impact on management, as shown by unchanged excessive levels of fishing mortality. Only after 1999 did fishing mortality begin to decrease slightly. Extrapolating a straight line fitted to the 75th percentile data for 1994–2007 suggests that 75% of the stocks would be fished at or below F_{msy} in 2048, if current trends continue. As rebuilding of stocks with ongoing fishing near F_{msy} will take many more years, this crude projection suggests that Europe will miss the 2015 deadline by substantially more than 30 years.

The time needed by stocks to reach B_{msy} is shown in Fig. 4 and in Table S5. In 12 stocks (22%) shown in the lower-left box in Fig 4, the time needed to reach B_{msy} without fishing is significantly larger than 5 years, i.e. even if fishing were halted in 2010, these stocks would miss the deadline for rebuilding in 2015. The stocks in the middle box would be able to rebuild by 2015 if fishing were halted in 2010. For the stocks in the upper part of the box, this might be achieved even with modest fishing pressure well below F_{msy}. The nine stocks in the upper-right box have current biomasses above B_{msy}.

Time to recovery

Environmental conditions in the Northeast Atlantic are gradually changing due to global climate change. This is likely to shift distributional ranges of commercial species towards the poles (Cheung *et al.* 2009) and may also impact on the population dynamics of the stocks. But no major changes are expected until 2015 (Keenlyside *et al.* 2008) and thus consideration of climate change has been excluded from this study. However, there is increasing evidence that depleted stocks are more vulnerable to climate change (Brander 2009) and thus rebuilding stocks will also rebuild their resilience.

Potential catches

Note that modest fishing of large stocks results in high catches at low cost. Current landings of the examined stocks were 7.6 million tonnes compared to maximum sustainable yields of 13.6 million tonnes. Current biomass of mature fish was 31.8 million tonnes compared to B_{msy} of 51.6 million tonnes. As cost of fishing is roughly inversely proportional to stock size, rebuilding overfished stocks to B_{msy} may result in a substantial reduction of cost for a given yield. Even if economic and ecosystem considerations result in precautionary catches that are lower than MSY (Grafton *et al.* 2007; Darimont *et al.* 2009), the potential gains from restoring depleted stocks are substantial and sufficient for 'the economic needs of coastal fishing communities' mentioned in UNCLOS (1982).

Status of stocks

Currently, only three stocks would qualify for certification by the Marine Stewardship Council (http://www.msc.org) as being in good status ($B \geq B_{msy}$) and sustainably managed ($F \leq F_{msy}$). These stocks are Baltic sprat, North-East Arctic saithe and Western horse mackerel. Six additional stocks had biomasses above B_{msy} and would be candidates for certification if fishing mortalities were reduced. These stocks are marked bold in Table S5.

In summary, of the stocks with current biomasses below B_{msy}, none will reach B_{msy} under current fishing pressure by 2015. Of the nine stocks currently above B_{msy}, four are heavily exploited and likely to shrink below target, suggesting that 49 (91%) of the examined stocks will fail to meet the goal of the *Johannesburg Plan of Implementation* under a 'business as usual' scenario. From a legal perspective, repeated enactment of fisheries management measures which are incapable of maintaining or restoring B_{msy}, does not seem to comply with the requirements contained in UNCLOS (Markus 2009).

The precautionary principle in European Law

Even if one would accept, for the sake of argument, that continuous uncertainty exists as to the sizes of fish stocks and the effectiveness of management measures, this would not entitle the EC to opt for less stringent management measures (Markus 2009). According to the precautionary principle, which is a binding principle of Community law [cf. Art. 174 (2) of the Treaty establishing the EC (EC Treaty 2002)], and explicitly referred to by Art. 2 (1) of the pertinent Council Regulation 2371/02 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy, it is impossible to justify the authorization of potentially environmental harmful activities by reference to the fact that scientific data on the possible negative impacts on the environment are insufficient, inconclusive, or uncertain. Pursuant to Art. 6 of the EC Treaty, the precautionary principle must be integrated into the definition and implementation of all Community policies and activities, in particular with a view to promoting sustainable development, and, therefore, also applies to the Common Fisheries Policy. Thus, enacting fisheries measures which ignore the precautionary principle, such as setting total allowable catch quotas (TACs) resulting in fishing mortalities that exceed the maximum reproductive potential, renders the Community organs in charge of fisheries responsible for a breach of EC law.

Different to the situation under the *Law of the Sea*, the obligation to comply with the precautionary principle under the EC Treaty is enforceable due to the existence of an obligatory jurisdiction. However, an action brought by the World Wildlife Fund (WWF) UK against the Commission and the Council in the Case T-91/07, which challenged the legality of the setting of TACs that violate the precautionary principle, was dismissed by the Court of First Instance on procedural grounds. It has recently been suggested that the reasons for the dismissal were neither convincing nor consistent with other European Court of Justice decisions (Markus 2009). Against this background, the outcome of the appeal initiated against that decision by the WWF (Case C-355/08 P) will be particularly relevant with regard to whether natural or legal persons may have legal standing to claim violations of the precautionary principle. In substance, even if the European Courts uphold their past jurisprudence whereby the Commission and the Council enjoyed a considerable discretion as to what level of precaution is needed [cf. Case C-405/92, (1993) ECR I-6133 para. 32], it seems well justifiable to argue that the systematic disregard of the precautionary principle in European fisheries management exceeds the limits of such discretion.

Lack of political will

Lack of political will has been identified as one of the main causes of the poor compliance with international agreements (Pitcher *et al.* 2009). Here is evidence from Europe: Apparently, fisheries managers have not asked ICES to provide estimates of the biomass limit B_{msy} and the corresponding fishing mortality F_{msy}, i.e. these internationally agreed reference points are not available to managers and are not used as targets. For example, the recent EU management plan for Cod in the western Baltic (ICES 2009) sets the target fishing mortality to $F = 0.6$, well above $F_{msy} = 0.27$ estimated in this study. The stock was outside of safe biological limits in 2009, yet, in accordance with the management plan, the total allowable catch for 2010 has been increased, keeping the stock in the unsafe zone for at least another year. Clearly, compliance with the Johannesburg Plan of Implementation (2002) was not on the agenda of European fisheries managers.

The ecosystem approach to fisheries

The ecosystem approach to fisheries management (EAFM) is widely accepted (e.g. EC 2009) and numerous studies have searched for new indicators to be used in this context (e.g. Piet and Rice 2004). However, one may question the realism of such new goals when for decades we have failed to implement the well-known basics of fisheries science. Clearly, stocks that are smaller than 20% of their unexploited biomass (median = 19% in 2007) are unable to fulfil their natural ecosystem roles as prey and predator. Rebuilding stocks to at least half of their unexploited biomass will go a long way towards the goals of EAFM (Froese *et al.* 2008).

Conclusion

In conclusion, if European Governments are serious about meeting their obligations to the *Law of the Sea*, the *Code of Conduct for Responsible Fisheries*, the *Johannesburg Plan of Implementation*, and the precautionary principle, they will have to reduce drastically fishing pressure and halt fishing completely on some of the European stocks. The socioeconomic impact of such reductions on fishermen, boat owners and fish-processing industry has not been assessed here. But given the ability to rebuild some stocks even within relatively short periods, the respective cost will, in all likelihood, be overcompensated by medium- to longer term gains in production and earnings.

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EC Treaty, consolidated version of 2002, Article 6. ''Environmental protection requirements must be integrated into the definition and implementation of the Community policies and activities referred to in Article 3, in particular with a view to promoting sustainable development.'' Article 174. ''(1). Community policy on the environment shall contribute to pursuit of the following objectives: – preserving, protecting and improving the quality of the environment; – protecting human health; – prudent and rational utilisation of natural resources; – promoting measures at international level to deal with regional or worldwide environmental problems. (2). Community policy on the environment shall aim at a high level of protection taking into account the diversity of situations in the various regions of the Community. It shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay.'' Article 230. ''The Court of Justice shall review the legality of acts adopted jointly by the European Parliament and the Council, of acts of the Council, of the Commission and of the ECB, other than recommendations and opinions, and of acts of the European Parliament intended to produce legal effects vis-à-vis third parties. It shall for this purpose have jurisdiction in actions brought by a Member State, the European Parliament, the Council or the Commission on grounds of lack of competence, infringement of an essential procedural requirement, infringement of this Treaty or of any rule of law relating to its application, or misuse of powers. The Court of Justice shall have jurisdiction under the same conditions in actions brought by the Court of Auditors and by the ECB for the purpose of protecting their prerogatives. Any natural or legal person may, under the same conditions, institute proceedings against a decision addressed to that person or against a decision which, although in the form of a regulation or a decision addressed to another person, is of direct and individual concern to the former. [...]''. EC Treaty, Offical Journal of the European Communities, **C325**, 33–184.

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UNCLOS (1982) *United Nations Convention on the Law of the Sea*, Article 61(3) states the need ''to maintain or restore populations of harvested species at levels which can

produce the maximum sustainable yield, as qualified by relevant environmental and economic factors, including the economic needs of coastal fishing communities and the special requirements of developing States, and taking into account fishing patterns, the interdependence of stocks and any generally recommended international minimum standards, whether subregional, regional or global.'' UNCLOS, Retrieved from www.un.org/Depts/los/convention_agreements/texts/unclos/closindx.htm.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Parameters derived from ICES stock assessment reports.

Table S2. Intermediate parameters.

Table S3. Results of the analysis of 54 stocks: MSY.

Table S4. Results of the analysis of 54 stocks: r_{max} and F_{msy}.

Table S5. Results of the analysis of 54 stocks: B_{msy} and Δt.

Table S6. Definition of symbols used in this study.

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